NISTIR 5101

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U.S. DEPARTMENT OF COMMERCE
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Report to
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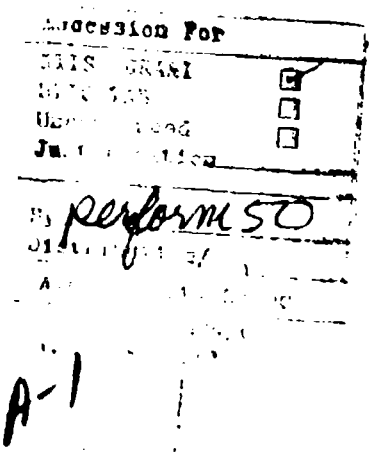
ABSTRACT

This report summarizes the research in ultrasonic measurements at the National Institute of Standards and Technology (NIST) which was supported in part by the Physics Division of the Office of Naval Research from 1982 to 1992. This represents work accomplished since the last such summary report, NBSIR 82-2529, entitled "Ultrasonic Research Summary Report and Literature Guide to the National Bureau of Standards/Office of Naval Research Program." References to the published literature documenting this new work are included.



INTRODUCTION

The ultrasonic research work summarized here was performed in the Ultrasonic Standards Group of the Automated Production Technology Division at the National Institute of Standards and Technology. It represents the highlights of the research sponsored in part by the Office of Naval Research from 1982 until 1992. Much of the work laid the foundation for subsequent calibration services, as was the case for acoustic emission and ultrasonic power.

ACCOMPLISHMENTS

The major accomplishments of the ultrasonic research sponsored by the Office of Naval Research from 1982 until 1992 and performed by the Ultrasonic Standards Group are summarized below. The list is divided into nine separate categories ordered somewhat chronologically, with some overlap occurring between categories.

I Conical Transducer Developments

- The NBS conical transducer was designed as a high fidelity, point pickup, acoustic emission piezoceramic sensor. One of the earlier versions possessed a cylindrically symmetric backing and housing which acted to dampen resonance artifacts and absorb unwanted reverberations in the mechanical system. Subsequent development led to an improved version with an irregularly shaped backing designed to smear out the reverberations that make their way back to the piezoceramic element. This resulted in the highest fidelity measurement to date of dynamic displacement by means of a piezoelectric transducer.[1,2]

- The correspondence between the electrical and mechanical descriptors of the conical transducer used as a point-force generator and point-displacement sensor were studied. The absolute calibration of the mechanical quantities such as force and velocity of the transducer allowed this direct correspondence to be made.[3]

- A high fidelity piezoelectric tangential displacement transducer was developed and evaluated for acoustic emission. Modal separation between the desired tangential mode and the unwanted normal mode was shown to exceed 30 dB.[4,5]

II Acoustic Emission Calibration Studies

- In a collaborative effort, two distinct methods of acoustic emission calibration were compared by the Nippon Steel Corporation in Japan and by the National Bureau of Standards in the United States. A comparison of the reciprocity method used in Japan with the surface-pulse method used in the United States demonstrated very good agreement for the absolute sensitivities of the six transducers calibrated.[6,7]

- The variables and fundamental limitations that pertain to acoustic emission sensitivity measurements were identified. These studies helped to quantify the NIST acoustic emission calibration precision, and led to meaningful comparisons between calibration results obtained using the NIST-based ASTM practice entitled "Standard Method for Primary Calibration of Acoustic Emission Sensors" and other calibration schemes.[8,9]

III Acoustic Emission Sources

• Many techniques to produce rapid transient disturbances in elastic media have been used by acoustic emission workers. The ideal source would be a "point," have a mathematically simple waveform, and possess a relatively large amplitude which could be determined *a priori*. In a study to compare several of the techniques, various sources using mechanical, electrical, and chemical devices were evaluated for their particular merits. [10]

• A Mil-Standard handbook was written to provide field operation assurance for acoustic emission system operation by means of simulated acoustic emission events. The recommended means was breaking pencil lead using the Hsu pencil source. [11]

IV Deconvolution Methodology Applications

• Measurements were successfully made at a remote location to determine the accurate dynamic force waveform of an impact on a plate structure. [12]

• Considering the acoustic emission output from a receiving transducer to be the convolution of the source waveform with the Green's function of the medium and the response function of the receiver, the deconvolution approach may be used to extract information about the source or the medium knowing the other two functions. The precision in the results that may be obtained by deconvolution was studied in terms of practical experimental limitations with real transducers. [13]

V Mathematical Analyses

• The capability of the deconvolution procedure for flaw characterization when using the inverse Gaussian function as the modeled probe source was evaluated and reported. This capability was based on a time domain deconvolution method for determining the impulse response of linear time invariant systems wherein the inverse Gaussian pulse is used to approximate the Dirac delta function. [14 15]

• A new mathematical technique was developed for the experimental determination in the time domain of the impulse response of linear systems. This development was pursued to address the difficulties encountered in the ill-posed deconvolution problem using a Green's function approach. The technique centered around the use of specifically designed probe waveforms that are approximations to the Dirac delta function or the Heaviside step function. This allowed for continuous deconvolution, a powerful option in the presence of noise, by smoothing out the singularities in the Green's function of the system. [16 17]

• The finite element method was used to study transient wave propagation in a plate. This study provided a basis for the impact-echo technique as a nondestructive test for flaw detection in concrete. The surface displacement

calculations due to point impact on a plate were in good agreement with those obtained using the Green's function solution. [18]

• A recently developed signal processing technique of B. Kidem using higher-order crossings was evaluated and adapted to acoustic emission signal discrimination. The mathematical concepts have unique physical significance to the physical problems of elastic wave propagation. [19]

VI Computer Software Developments

• The inverse problem in acoustic emission was addressed. Specifically, a procedure for determining the force-time function of a point force of unknown nature as applied to a solid was described and implemented in computer code. [20 21]

• The mechanics part of acoustic emission detection was evaluated in a fundamental study, and practical applications for the technique were presented. A computer program was developed based on the Green's function formulation to predict the acoustic emission waveforms knowing the source and the medium's elastic properties for the case of an infinite plate. [22 23 24]

• Computer algorithms were derived for the dynamic Green's function which can be used to determine the response of ultrasonic receivers to the scattered energy in specific materials insonified by the output of known sources. One specific configuration, involving two transducers in a liquid medium facing a solid specimen, was emphasized for its practical application to materials testing. [25]

VII Solid Materials Applications

• The point source-point receiver methodology was successfully applied to the study of flaws in hardened concrete. A dropping steel ball was the source and a conical broadband displacement transducer was the receiver. With the help of numerical solutions for the response of an infinite plate to surface impact in order to interpret experimental signal traces, the location and extent of simulated flaws embedded within the concrete were determined. [26]

• An approach to characterize the ultrasonic wave field (inside a solid) produced by a piezoelectric transducer was demonstrated. The steps of this approach consisted of (a) the photoelastic visualization of the moving pulse in a transparent solid, (b) a point displacement field measurement at the plate epicenter, and (c) dynamic transient wave field analysis using a finite element technique. [27]

• A simple technique was reported, in which the echo waveform generated by a point impulse and received by a point normal displacement transducer was used to determine the longitudinal, shear, and Rayleigh wave speeds. The NBS conical transducer was used as an example for a point source generator and point displacement detector. [28]

• The influence of interface conditions on the behavior of transient waves were studied for a structure consisting of an isotropic layer overlay on an isotropic half-space. The generalized ray expansion technique with the Willis inversion method was used. The theory predicts results that are highly dependent upon the properties of the interface bond. Experimental waveforms can, therefore, elucidate the condition of a bond. [29]

VIII Ultrasonic Power Sources

• Quartz transducers designed and fabricated at NIST as stable transmitters of ultrasonic power were evaluated as potential power standards. An international intercomparison of measurements of the power emitted by these standards was made, and the results reported by NIST serving as the pilot laboratory. [30]

• The NIST ultrasonic absolute power transfer standard, Standard Reference Material 1855, was developed and offered for distribution in order to provide the medical community in particular with a means to evaluate the radiation output of its clinical ultrasonic equipment. The contribution of this reference standard to the medical profession is recognized by its inclusion in a recent text on ultrasonic exposimetry. [31] [32]

IX Miscellaneous

• The various ultrasonic measurement services offered by NIST, and undergoing continuous improvement over the past decade with support from the ONR program for research in ultrasound, were reviewed and summarized at the recent National Conference of Standards Laboratories in Washington, DC. [33]

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